Notice No.3

Rules for the
Manufacture, Testing and Certification of Materials, July 2021

The status of this Rule set is amended as shown and is now to be read in conjunction with this and prior Notices. Any corrigenda included in the Notice are effective immediately.

Please note that corrigenda amends to paragraphs, Tables and Figures are not shown in their entirety.

Issue date: June 2022

Amendments to	Effective date	IACS/IMO implementation (if applicable)
Chapter 1, Sections 2 & 3	1 July 2022	N/A
Chapter 1, Section 6	1 July 2022	1 July 2022
Chapter 2, Sections 1 & 3	1 July 2022	N/A
Chapter 3, Section 6	1 July 2022	1 July 2022
Chapter 3, Section 6	1 July 2022	N/A
Chapter 4, Sections 1 & 9	1 July 2022	N/A
Chapter 4, Sections 1, 2, 3, 4, 5, 6, 7, 8 & 9	1 July 2022	1 July 2022
Chapter 5, Sections 1, 2, 3, 4, 5 & 9	1 July 2022	1 July 2022
Chapter 6, Section 1	1 July 2022	N/A

Chapter 1
General Requirements

■ *Section 2*
Approval and survey requirements

2.4 Materials Quality Scheme

2.4.1 The manufacturer may apply to be approved under the Materials Quality Scheme where the following requirements are met:

(a) The manufacturer has been approved by LR on the Materials Survey Scheme for a minimum of three years and continues to maintain their LR works approval according to *Ch 1, 2.2 LR Approval – General 2.2.14*; and

(b) The manufacturer has a quality management system, which has been certified as meeting the requirements of ISO 9001 *Quality Management Systems - Requirements* by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum; and

(c) The manufacturer has a satisfactory history of quality performance in the manufacture and supply of LR approved materials.

2.4.8 The procedures for application for approval for the Materials Quality Scheme are given in ~~Book M of LR's *Materials and Qualification Procedures for Ships (MQPS)*~~ LR's ShipRight Procedure *Approval of a Manufacturer according to Quality Assurance Engineering Schemes (QAES)*.

2.4.15 Once every three years, a full assessment of scheme compliance will be conducted by a Surveyor who is generally not the regular attending Surveyor. This assessment is in addition to the periodic inspection requirement made according to *Ch 1, 2.2 LR Approval – General 2.2.14*.

■ *Section 3*
Certification of materials

3.1 General

3.1.3 The following certificate types are to be used, (a) and (b) for the Materials Survey Scheme, and (d) for the Materials Quality Scheme:

(a) **LR Certificate**
This type of certificate is issued by LR based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules.

(b) **Manufacturer's certificate validated by LR**
A manufacturer's certificate, validated by LR on the basis of inspection and testing carried out by the manufacturer and which is in accordance with the requirements of these Rules, may be accepted. In this case, the certificate will include the following statement:
~~"~~"We hereby certify that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register."~~"~~

(c) **Manufacturer's certificate**
This type of certificate is issued by the manufacturer based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules or the applicable National or International ~~s~~Standard. The certificate is to be validated by the manufacturer's authorised representative, independent of the manufacturing department. The certificate will contain a declaration that the products are in compliance with the requirements of these Rules or the applicable National or International ~~s~~Standard.

(d) **Manufacturer's certificate issued under the Materials Quality Scheme**
Where a manufacturer is approved according to the Materials Quality Scheme, they will issue manufacturer's certificates bearing the scheme mark and the MQS approval number. The certificates must also bear statements as described in LR's ShipRight Procedure *Approval of a Manufacturer according to Quality Assurance Engineering Schemes (QAES).* These statements by the manufacturer will certify that the product has been made by an approved process in accordance with LR's Rules and that the certificate is issued in accordance with the requirements of the MQS. ~~the following statement:~~
~~"This certificate is issued under the arrangements authorised by Lloyd's Register (operating group) in accordance with the requirements of the Materials Quality Scheme and scheme number MQS ……."~~

3.1.4 The certificate format is to be approved by LR. Variations in the wording of the statements are permitted with written approval from LR.

3.1.5 ~~3.1.4~~ Where these Rules allow for the issue of a manufacturer's certificate for materials, either validated by an LR Surveyor, or bearing the Materials Quality Scheme mark, the manufacturer is to ensure that a copy of the certificate is supplied to LR by an agreed means and frequency.

■ *Section 6*
References

6.1 General

Table 1.6.1 List of National and International Standards and Codes

Rule reference	Standard
Chapter 4 – Steel Castings	ISO 1161 ASTM A991 ASTM E446 ASTM E186 ASTM E280 ISO 4993 EN 12680-1 EN 12680-2 EN 1371-1
Chapter 5 – Steel Forgings	ASTM E112 ASTM A991 ASTM A745/A745M EN 10228-4 ANSI/ASNT CP 189 ISO 9712

Chapter 2
Testing Procedures for Metallic Materials

■ *Section 1*
General requirements for testing

1.2 Testing machines

1.2.1 All tests are to be carried out by competent personnel. Testing machines are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. This calibration is to be carried out by nationally accredited organisations. ~~of standing that have been approved or recognised by a Naval Authority and~~ Testing machine condition and calibration are to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house.

■ *Section 3*
Impact tests

3.2 Testing procedures

3.2.1 All impact tests are to be carried out on Charpy machines ~~approved~~ accepted by Lloyd's Register (hereinafter referred to as LR) in accordance with the requirements of *Ch 2, 1.2 Testing machines 1.2.1* and having a striking energy of not less than 150 J.

Chapter 3
Rolled Steel Plates, Strip, Sections and Bars

■ *Section 6*
Carbon–manganese and nickel alloy steels for low temperature service

6.1 Scope

6.1.3 Provision is made for plates and sections up to ~~40 mm~~ 50 mm thick.

6.1.4 ~~Steels with alternative chemical compositions or mechanical properties or in a different supply condition may be given special consideration.~~ Alternative steels which comply with National Standard specifications may be accepted under special consideration provided that these specifications give equivalence to the requirements of this Chapter or alternatively are approved for a specific application. For plates of thickness greater than 40 mm and up to 50 mm that are accepted in accordance with a National Standard specification, in addition to each set of impact tests required by the standard, a set of impact tests is required at mid-thickness position; the orientation and acceptance criteria are to be the same as those required by *Ch 3, 6.4 Mechanical tests*.

6.1.5 The requirements for selection of grades and thickness for plates for appropriate minimum design temperatures are given in the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* and the *Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels*.

6.1.6 For high manganese austenitic steels with thickness up to 40 mm, the specific requirements for approval, manufacturing and inspection are specified in LR's *Guidance Notes for Approval, Manufacture, Testing and Certification of High Manganese Austenitic Steel for Low Temperature Service.*

6.2 Manufacture and chemical composition

(Part only shown)

Table 3.6.1 Chemical compositions of nickel alloy steels

Grade of steel	C	Si	Mn	Ni	P	S	Residual elements	Aluminium (*see* Note 1)

Note 1: The specified minimum aluminium content may not be applicable when an alternative grain refining method is approved.

6.4 Mechanical tests

(Part only shown)

Table 3.6.3 Mechanical properties for acceptance purposes (*see* Note 1)

Grade of steel	Yield stress N/mm^2 min.	Tensile strength N/mm^2	Elongation on 5.65 % min.		Charpy V-notch impact tests (*see* Note 3)	
					Test temp. °C	Impact energy
						Plates – transverse tests Average energy 27 J min Sections and bars – longitudinal tests Average energy 41 J min
1½ Ni	275	490 – 640	22		-65	
2 ¼ Ni	275	490 – 640	21		-70	
3½ Ni	285	450 – 610	21		-95	
5Ni	390	540 – 740	21		-110	
9Ni	~~490~~585	~~640~~680 – ~~790~~820	18		-196	

Note *1*. These requirements are applicable to products not exceeding ~~40~~50 mm in thickness. The requirements for thicker products for approved applications are subject to agreement.

~~**Note** *2*. The minimum design temperatures at which plates of different thicknesses in the above grades may be used are given in Figure 3.6.1 Minimum design temperatures for carbon-manganese grades and Figure 3.6.2 Minimum design temperatures for nickel grades. Consideration will be given to the use of thicknesses greater than those in the Tables or to the use of design temperatures below –165°C.~~

6.6 Certification of materials

Existing Figure 3.6.1 and Figure 3.6.2 have been deleted in their entirety.

Chapter 4
Steel Castings

■ *Section 1*
General requirements

1.3 Quality of Castings

1.3.4 In the event of any casting proving to be defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.7 Visual and surface ~~non-destructive examination~~ Non-Destructive Examination

1.7.2 All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, and shot or sand blasting. Castings are to be examined in the final delivery condition. Where a casting is supplied in semi-finished condition, the manufacturer is to take into account the quality level, including the functional and performance requirements, of final finished machined components.

1.7.4 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer, and a report on the relevant examinations is to be submitted to the Surveyor, who may require checks to be made and to witness such checks. Where intermediate inspections have been performed, the manufacturer is to provide reports of the results upon the request of the Surveyor.

1.7.5 All castings are to be subjected to 100 per cent visual examination of all accessible surfaces by the manufacturer and are then to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces. Castings are to be subject to magnetic particle examination or ~~dye~~ liquid penetrant ~~inspection~~ testing (for austenitic stainless steel castings, *see Ch 4, 8 Stainless steel castings*) in accordance with *Ch 4, 1.7 Visual and ~~non-destructive examination~~ Non-Destructive Examination 1.7.9*, unless more specific requirements for ~~non-destructive examination~~ Non-Destructive Examination are included in subsequent Sections of this Chapter, other parts of the Rules or the agreed specification. Viewing conditions at the inspected surfaces are to be in accordance with a nationally or internationally recognised standard.

1.7.6 Where specified or required by the Rules~~non-destructive examination~~, Non-Destructive Examination is to be carried out before acceptance. All tests are to be in accordance with the requirements of *Ch 1, 5 Non-destructive examination*. Non-destructive testing applied for acceptance purposes to support final casting certification is to be made after the final heat treatment of the casting.

1.7.9 Where required, magnetic particle or ~~dye~~ liquid penetrant testing is to be carried out by the manufacturer whenever appropriate and also when the castings are in the finished condition. For surface inspection NDT methods, the surface quality is to be a minimum value of R_a less than or equal to 6,3 µm. The tests are to be made in the presence of the Surveyor unless otherwise specially agreed. The castings are to be examined in the following areas in addition to any areas defined in subsequent Sections of this Chapter:

(a) At all accessible fillets and changes of section.
(b) At positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging.
(c) In way of fabrication weld preparations, for a distance not less than 50 mm from the edge.
(d) In way of welds.
(e) In way of chaplets.
(f) At other positions agreed with the Surveyor to include areas which may be subjected to high stress in service.

Existing paragraph 1.7.10 has been re numbered / re-inserted in Section 1.8.

~~1.7.11~~ 1.7.10 ~~Radiographic examination, where required, is to be carried out by the manufacturer in areas generally as indicated for ultrasonic examination in *Ch 4, 1.7 Visual and non-destructive examination 1.7.10*. All radiographs are to be submitted to the Surveyor for examination and acceptance. The radiographic technique and acceptance standards are to be to the satisfaction of the Surveyor and in accordance with any requirements of the approved specification.~~ The testing procedures, apparatus and conditions of magnetic particle testing and liquid penetrant testing are to comply with recognised National or International Standards. Magnetic particle testing is preferable to penetrant testing except in the following cases:

(a) Austenitic stainless steels.
(b) Interpretation of open visual or magnetic particle indications.
(c) At the instruction of the Surveyor, where a particular need for penetrant testing has been identified.

1.7.11 For magnetic particle testing, attention is to be paid to the contact between the casting and the clamping devices of stationary magnetisation benches in order to avoid local overheating or burning damage at the casting's surface. Prods are not permitted on finished machined items. Note that the use of solid copper at the prod tips must be avoided due to the risk of copper contamination of the casting. The poles of the magnets are to have close contact with the component.

Existing paragraphs 1.7.12 and 1.7.13 have been deleted and replaced with the below:

1.7.12 The AC magnetisation method is normally used, as it is more sensitive for detecting surface indications. Where the DC magnetisation method is used, this is to be in agreement with LR, and the reason for use clearly justified.

1.7.13 When indications have been detected as a result of the surface inspection, acceptance or rejection is to be decided in accordance with *Table 4.2.2 Acceptance criteria for surface inspection evaluation*.

Existing paragraphs 1.7.14 and 1.7.15 have been deleted.

1.8 Volumetric Non-Destructive Examination

1.8.1 Where required by subsequent Sections or by the agreed specification, ultrasonic examination is to be carried out by the manufacturer, but Surveyors may request to be present in order to verify that the examination is carried out in accordance with the agreed procedure. Ultrasonic testing is to be carried out after the castings have been ground, machined or shot blasted to a suitable condition, with a minimum value surface quality of R_a less than or equal to 12,5 µm. The surfaces of castings to be examined are to be such that adequate coupling can be established between the probe and the casting and that excessive wear of the probe is avoided. This examination is to be carried out in the following areas:

(a) At positions which may be subjected to high stresses in service, as agreed with the Surveyor.
(b) In way of fabrication weld preparations, for a distance not less than 50 mm from the edge.
(c) At positions where subsequent machining may expose filamentary shrinkage or other defects (e.g. bolt holes, bearing bores).
(d) In way of welding.
(e) In way of riser positions.
(f) At positions where experience shows that significant internal defects may occur – these are to be agreed between the manufacturer and the Surveyor.

1.8.2 In the case of castings such as rudder horns, which may have a large surface area still untested after the above inspections have been applied, an additional ultrasonic inspection of the untested areas is to be made along continuous perpendicular grid lines on nominal 225 mm centres, scanning may be from one surface only.

1.8.3 Volumetric inspection is normally to be carried out by ultrasonic testing using the contact method with normal (0°) beam and/or angle beam technique. The testing procedures, apparatus and conditions of ultrasonic testing are to comply with the recognised National or International Standards.

1.8.4 Advanced NDE methods, as described in *Ch 1, 5.11 Advanced Non-Destructive Examination methods*, may be applied to castings, as appropriate to the material type, thickness, complexity and geometry. Acceptance and rejection criteria are specified in *Table 4.2.3 Ultrasonic acceptance criteria for castings – Using DGS or DAC system*.

1.8.5 In some cases, due to the shape, nature, or complexity of casting, or defect type or orientation, there may be a need for radiographic testing. In such cases, radiographic testing may be carried out on the basis of prior agreement with LR. Where radiographic testing is to be used, National or International Standards for both the testing method and the quality or severity level to be applied, is to be agreed with LR. These following examples are suitable National or International Standards as appropriate to the radiographic testing of castings, and casting thickness.

- ASTM E446;
- ASTM E186;
- ASTM E280;
- ISO 4993.

1.8.6 Radiographic examination, where required, is to be carried out by the manufacturer in areas generally as indicated for ultrasonic examination in *Ch 4, 1.8 Volumetric Non-Destructive Examination 1.8.1*. All radiographs are to be submitted to the Surveyor for review and acceptance. The radiographic technique and acceptance standards are to be to the satisfaction of the Surveyor and in accordance with any requirements of the approved procedure.

1.8.7 A suitable quality level for marine castings would normally be severity Level 2 or 3 (of the above standards), or as specified by the design authority, depending on the location zone and type of casting. Other severity levels may be applied and are to be agreed with LR.

1.8.8 Only those areas shown in the agreed inspection plan should be tested; however, the inspections may reveal indications that require further evaluation or an extension of testing. In such cases, this is to be agreed with LR. The plan is to include those locations nominated in *Ch 4, 1.7 Visual and surface Non-Destructive Examination 1.7.9* and *Ch 4, 1.7 Visual and surface Non-Destructive Examination 1.7.14*, together with the scanning zones identified for the relevant casting in the appropriate Sections of this Chapter.

1.8.9 Ultrasonic scans should be made using a 0° probe of 1–4 MHz (usually 2 MHz) frequency, and angle probes, where required. Whenever possible, scanning is to be performed from both surfaces of the casting and from surfaces perpendicular to each other.

1.8.10 The back wall echo obtained on parallel sections is to be used to monitor variations in probe coupling and material attenuation. Any reduction in the amplitude of the back wall echo due to material properties is to be corrected. Attenuation in excess of 30 dB/m could be indicative of an unsatisfactory annealing heat treatment and may adversely affect the testing and void the results. In such cases of excessive attenuation, this is to be investigated, and suitable mitigation measures carried out for effective ultrasonic testing to continue, where possible.

1.8.11 Machined surfaces, especially those in the vicinity of riser locations and in the bores of stern boss castings, are to also be subject to a near surface (approximately 25 mm) scan using a twin crystal 0° probe.

1.8.12 Additional scans on machined surfaces are of particular importance in cases where bolt holes are to be drilled or where surplus material such as 'padding' has been removed by machining, thus moving the scanning surface closer to possible areas of shrinkage.

1.8.13 Additionally, where possible, examination of the machined bores of castings using circumferential scans with 70° probes are to be carried out in order that axial radial planar flaws such as hot tears can be detected. Fillet radii are to be examined using 45°, 60° or 70° probes scanning from the surfaces/direction likely to give the best reflection, primarily to determine the presence of any cracks within the radiused areas, and as an additional scan to confirm any indications that may have been detected with 0° probe(s) within this area.

1.8.14 In the examinations of those zones nominated for ultrasonic examination, the reference sensitivity for the 0° probe is to be established against a 6 mm reflector. Sensitivity can be calibrated either against 6 mm diameter flat bottomed hole(s) in a reference block (or series of blocks) corresponding to the thickness of the casting provided that a transfer correction is made, using the DAC (Distance-Amplitude-Correction) method, or by using the DGS (Distance-Gain-Size) method.

1.8.15 Where angle probes are used the reference sensitivity is to be established against an appropriate 6 mm reflector (e.g. reference reflectors angled perpendicular to the sound beam) for the DAC method, or equivalent using the DGS method.

1.8.16 The DGS diagrams issued by a probe manufacturer are to be used as they identify the difference in dB between the amplitude of a back wall echo and that expected from a 6 mm diameter disc reflector. By adding this difference to the sensitivity level initially set by adjusting a back wall echo to a reference height, e.g. 80 per cent, the amended reference level will be representative of a 6 mm diameter disc reflector. Similar calculations can be used for evaluation purposes to establish the difference in dB between a back wall reflector and disc reflectors of other diameters, such as 12 or 15 mm.

1.8.17 Following Transfer Correction, differences in attenuation or surface condition between the reference block and the casting, any indications received from the nominated zones in the casting that exceed the 6 mm reference level are to be marked for evaluation against the acceptance criteria given in *Table 4.2.3 Ultrasonic acceptance criteria for castings – Using DGS or DAC system*. Evaluation is to include additional scans with angle probes in order that the full extent of the discontinuity can be plotted.

1.8.18 The general acceptance criteria given in *Table 4.2.3 Ultrasonic acceptance criteria for castings – Using DGS or DAC system* are to be applied where no specific acceptance criteria are stated in the subsequent Sections of this Chapter.

1.9 Reporting and personnel certification

1.9.1 All NDE, including personnel, procedural, test method and reporting criteria, is to be in accordance with the requirements of *Ch 1, 5 Non-destructive examination*, and applicable Sections for NDE methods. In addition, reports of surface inspections are to include at least the following items:

- For penetrant testing, the penetrant system used.
- For magnetic testing, the method of magnetising, test media, and magnetic field strength and magnetic flux indicators (where appropriate).

1.9.2 The reporting criteria for ultrasonic inspection are to be in accordance with the requirements of *Ch 1, 5.6 Non-destructive examination reports* and *Ch 1, 5.10 Ultrasonic testing*. In addition, reports of ultrasonic inspections should include at least the following items:

- Flaw detector.

- Probe type, size, angle and frequency.
- Calibration and reference blocks used.
- Sensitivity method including reflector size and transfer correction.
- Maximum scanning rate.
- Couplant.

1.9.3 Personnel engaged in visual examination are to have sufficient knowledge and experience; however, they may be exempted from formal qualifications.

1.9.4 The NDT personnel's certificates and competence are to comprise all industrial sectors and techniques being applied by the manufacturer or its sub-contractors. Certificates are to be made available to LR for verification, when requested.

1.9.5 The operator carrying out the NDT and interpreting indications should, as a minimum, be qualified and certified to Level II in the NDT method(s) concerned. However, operators only undertaking the gathering of data using any NDT method and not performing data interpretation or data analysis may be qualified and certified as appropriate, at Level I. The operator is to have adequate knowledge of materials, weld, structures or components, NDT equipment and limitations to apply the relevant NDT method for each application appropriately.

~~1.8~~ 1.10 Pressure testing

Existing paragraph 1.8.1 has been renumbered 1.10.1.

~~1.9~~ 1.11 Rectification and dressing of castings

~~1.9.1~~ 1.11.1 When unacceptable defects are found in a casting, these are to be removed by machining or chipping. Flame-scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting excavation are subsequently ground smooth. Complete elimination of the defective material is to be proven by adequate ~~non-destructive examination~~ Non-Destructive Examination. Shallow grooves or excavations resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding. Complete elimination of the defective material is to be verified by magnetic particle or ~~dye~~ liquid penetrant testing.

Existing paragraphs 1.9.2 to 1.9.5 have been renumbered 1.11.2 to 1.11.5.

~~1.9.6~~ 1.11.6 All welding is to be carried out by an approved welder and in accordance with an approved welding procedure which includes the features referred to in *Ch 4, ~~1.9~~ 1.11 Rectification and dressing of castings ~~1.9.6~~ 1.11.6* to *Ch 4, ~~1.9~~ 1.11 Rectification and dressing of castings ~~1.9.13~~ 1.11.14*. The welding procedures and welders are to be qualified in accordance with *Ch 12 Welding Qualifications*.

Existing paragraphs 1.9.7 to 1.9.10 have been renumbered 1.11.7 to 1.11.10.

~~1.9.11~~ 1.11.11 The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. The use of low hydrogen type welding consumables is preferred. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in *Ch 4, ~~1.9~~ 1.11 Rectification and dressing of castings ~~1.9.12~~ 1.11.13*, and the results of these tests are to be presented to the Surveyor.

Existing paragraphs 1.9.12 and 1.9.13 have been renumbered 1.11.12 and 1.11.13.

~~1.9.14~~ 1.11.14 On completion of heat treatment, all welds and adjacent material are to be ground smooth and examined by magnetic particle~~,~~ or ~~liquid~~ penetrant testing, ultrasonic or radiographic examination. The Surveyor is to attend at these inspections, to witness the results of magnetic particle or ~~liquid~~ penetrant examination and to examine any radiographs. Satisfactory results are to be obtained from all forms of ~~non-destructive examination~~ Non-Destructive Examination used. The acceptance criteria for the NDE of welds are to be in accordance with subsequent Sections of this Chapter or where these do not exist, *Table 13.2.5 Acceptance criteria for visual testing, magnetic particle and liquid penetrant testing* to *Table 13.2.7 Acceptance criteria for ultrasonic and phased array testing*, as appropriate.

Existing paragraphs 1.9.15 to 1.9.17 have been renumbered 1.11.15 to 1.11.17.

Existing sub-Section 1.10 has been renumbered 1.12.

~~1.11~~ 1.13 Certification of materials

Existing paragraphs 1.11.1 and 1.11.2 have been renumbered 1.13.1 and 1.13.2.

~~1.11.3~~ 1.13.3 Where applicable, the manufacturer is to provide a signed report regarding ~~non-destructive examination~~ Non-Destructive Examination as required by *Ch 4, 1.7 Visual and ~~non-destructive examination~~ surface Non-Destructive Examination 1.7.7* together with a statement and/or a sketch detailing the extent and position of all weld repairs made to each casting as required by *Ch 4, ~~1.9~~ 1.11 Rectification and dressing of castings ~~1.9.5~~ 1.11.5* or the statement detailed in *Ch 4, ~~1.9~~ 1.11 Rectification and dressing of castings ~~1.9.15~~ 1.11.15*.

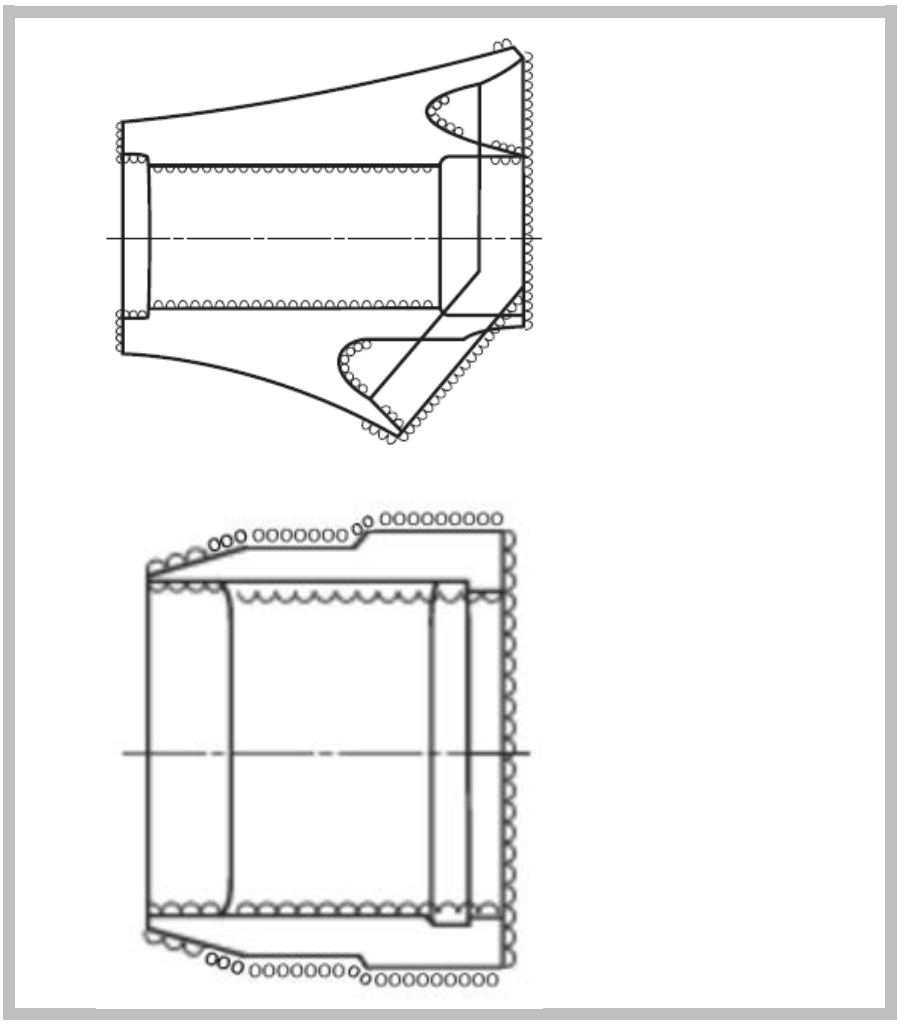
■ *Section 2*
Castings for ship and other structural applications

2.5 Non-~~destructive examination~~ Destructive Examination

2.5.1 Castings used in ship construction for the sternframe, rudder and propeller shaft supports are to be examined by ultrasonic and magnetic particle methods in accordance with *~~Ch 4, 1.7 Visual and non-destructive examination~~ Ch 4, 1.7 Visual and surface Non-Destructive Examination (NDE)* and *Ch 4, 1.8 Volumetric Non-Destructive Examination*. The type and extent of ~~non-destructive examination~~ Non-Destructive Examination of castings for other structural applications are to be specially agreed by the Surveyor.

2.5.2 The extent and methods of ~~non-destructive examination~~ Non-Destructive Examination to be applied to typical hull steel castings are shown in *Figure 4.2.1 Extent of non-destructive evaluation for stern frame castings* to *Figure 4.2.6 Extent of non-destructive evaluation for rudder (lower part) castings* in addition to the areas specified in *~~Ch 4, 1.7 Visual and non-destructive examination 1.7.9~~ Ch 4, 1.7 Visual and surface Non-Destructive Examination (NDE) 1.7.9* and *~~Ch 4, 1.7 Visual and non-destructive examination 1.7.10~~ Ch 4, 1.8 Volumetric NDE 1.8.1*.

Existing Figure 4.2.3 has been replaced with the Figure below:



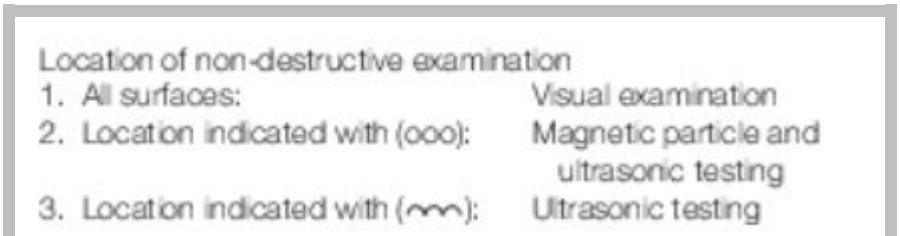


Figure 4.2.3 Extent of non-destructive evaluation for stern boss castings

2.5.3 Acceptance levels for visual inspection are to be taken as follows:

(a) No cracks, crack-like indications, ~~or~~ hot tears or cold shuts are permitted.

(b) Castings are to be free of other injurious indications to the satisfaction of the Surveyor.

~~(c) Additional magnetic particle, dye penetrant or ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor. These examinations are in addition to those required by *Ch 4, 2.6 Acceptance levels for NDE of castings*.~~

(c) Thickness of the remains of sprues or risers should be within casting dimensional tolerance.

(d) Additional magnetic particle, liquid penetrant or ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor. These examinations are in addition to those required by *Ch 4, 2.6 Acceptance levels for Non-Destructive Examination of castings*.

2.6 Acceptance levels for ~~NDE~~ Non-Destructive Examination of castings

2.6.1 The following definitions apply to indications associated with magnetic particle and ~~dye~~ liquid penetrant ~~inspection~~ testing:

(a) **Linear indication**. An indication ~~in which the length is at least three times the width~~ with a largest dimension three or more times its smallest dimension (i.e. $l \geq 3w$).

(b) **Non-linear indication**. An indication ~~of circular or elliptical shape with a length less than three times the width~~ with a largest dimension less than three times its smallest dimension (i.e. $l < 3w$).

(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less edge-to-edge~~.~~, which results in a unique indication defined as follows:

- Non-linear indications form an alignment when the distance between indications is less than 2 mm and at least three indications are aligned. An alignment of indications is considered to be a unique indication and its length is equal to the overall length of the alignment.
- Linear indications form an alignment when the distance between two indications is smaller than the length of the longest indication.

(d) **Open indication**. An indication visible after removal of the magnetic particles or that can be detected by the use of contrast ~~dye~~ liquid penetrant testing.

(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast ~~dye~~ liquid penetrant testing.

(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant for the categorisation of indications.

2.6.2 For the purpose of evaluating indications, the surface is to be divided into reference band length of 150 mm for Level MT1/PT1 and into reference areas of ~~225 cm^2~~ 22500 mm^2 for Level MT2/PT2. The band length and/or area is to be taken in the most unfavourable location relative to the indications being evaluated.

2.6.3 The following quality levels recommended for magnetic particle testing (MT) and/or ~~dye~~ liquid penetrant testing (PT) are~~:~~:

(a) Level MT1/PT1 – fabrication weld preparation areas.

(b) Level MT2/PT2 – other locations indicated on *Figure 4.2.1 Extent of non-destructive evaluation for stern frame castings* to *Figure 4.2.6 Extent of non-destructive evaluation for rudder (lower part) castings*.

The allowable number and sizes of indications in the reference area are shown in the acceptance criteria ~~are shown~~ detailed in *Table 4.2.2 Acceptance criteria for surface inspection evaluation*. Cracks, cold shuts and hot tears are not acceptable.

Existing Table 4.2.2 has been deleted and replaced with the Table below.

Table 4.2.2 Acceptance criteria for surface inspection evaluation

Quality level	Maximum number of indications	Type of indication	Maximum number of each type	Maximum dimension of single indication, mm (*see* Note 2)
MT1/PT1	4 in 150 mm length	Non-linear	4 (*see* Note 1)	5
		Linear	4 (*see* Note 1)	3
		Aligned	4 (*see* Note 1)	3

MT2/PT2	20 in 22500 mm^2 area	Non-linear Linear Aligned	10 6 6	7 5 5
Note *1.* Minimum of 30 mm (measured in any direction) between relevant indications. Note *2.* In weld repairs, the maximum dimension is 2 mm.				

2.6.4 Acceptance criteria for ultrasonic testing are shown in *Table 4.2.3 Ultrasonic acceptance criteria for marine steel castings* as UT1 and UT2. Discontinuities within the examined zones interpreted to be cracks, cold shuts or hot tears are not acceptable.

Existing Table 4.2.3 has been deleted and replaced with the Table below.

Table 4.2.3 Ultrasonic Acceptance Criteria for steel castings – Using DGS or DAC system

Quality level	Allowable disc shape according to DGS, mm (*see* Note 1) or Diameter of FBH according to DAC curve, mm (*see* Notes 2 & 3)	Maximum number of indications to be registered (*see* Note 4)	Allowable size of all relevant indications, mm (*see* Notes 5 & 6)
UT1	>6	0	0
UT2	12–15 >15	5 0	50 0
Note *1.* DGS – Distance Gain Size. **Note** *2.* DAC – Distance Amplitude Correction. **Note** *3.* The corresponding DAC level to each of the Flat Bottom Hole (FBH) reflectors is at 100% DAC. **Note** *4.* Grouped in an area measuring 300 x 300 mm. **Note** *5.* Measured on the scanning surface. **Note** *6.* The measured indication is regarded as the longest dimension, as measured in the scanning process.			

2.6.9 The maximum number of indications to be recorded and the maximum length of indications permissible for quality Level UT2 apply to normal probes.

2.6.10 For quality Level UT2, any discontinuity producing a signal amplitude in excess of the 15 mm DAC curve is to be regarded as unacceptable.

2.6.11 Any signal between 12 mm FBH + 15 mm FBH curve is to be evaluated for length of defect.

2.6.12 For near surface testing, to an approximate depth of 25 mm, a twin crystal 0° - normal beam - probe should be used, plus a single crystal 0° probe, beyond a depth of 25 mm, for the remaining volume.

2.6.13 Ultrasonic acceptance criteria for other casting areas not specified in *Figure 4.2.1 Extent of non-destructive evaluation for stern frame castings* to *Figure 4.2.6 Extent of non-destructive evaluation for rudder (lower part) castings* is to be subject to special consideration based on the anticipated stress levels during service and the type, size and position of the discontinuity.

2.6.14 DGS and DAC methods may be used for determining sensitivity. The DAC method for normal beam probes may be based on a 6 mm diameter reflector or FBH. A DAC curve is to be produced using reference blocks containing 6 mm FBH reflectors over a range representative of the inspection thickness, after adjustment for transfer and attenuation losses.

2.6.15 For quality Level UT1, any discontinuity producing a signal amplitude in excess of the 6 mm DAC curve is unacceptable.

2.6.16 For quality Level UT2, the sensitivity may be based on actual size FBH (of 12 mm and 15 mm) or based on equivalent 6 mm FBH, and the sensitivity adjusted to obtain equivalent amplitudes, as described in *Ch 4, 2.6 Acceptance levels for Non-Destructive Examination of castings 2.6.17*.

2.6.17 When setting sensitivity using 6mm FBH, adjustment of signal amplitudes - measured in dB above 6 mm DAC - can be determined for 12 mm and 15 mm FBH reflectors, i.e. DAC + 12 dB and DAC + 16 dB, plus any compensation for transfer and attenuation losses, as illustrated in *Figure 4.2.7 DAC curve produced from 6 mm FBH reflector and DAC curves adjusted to represent equivalent 12 mm and 15 mm FBH reflectors*. The increase in dB to the indicated levels represents the equivalent FBH sizes (for 12 mm and 15 mm), and their respective corresponding ultrasonic response amplitudes.

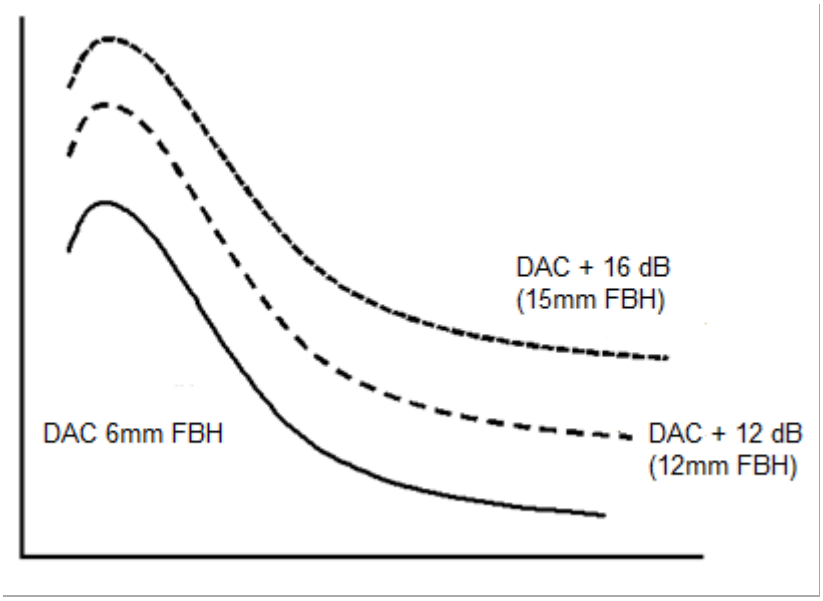


Figure 4.2.7 DAC curve produced from 6 mm FBH reflector and DAC curves adjusted to represent equivalent 12 mm and 15 mm FBH reflectors

Explanatory note for DAC and Figure 4.2.7

- The bottom curve (DAC) represents a sensitivity based on 6 mm FBH, and the two additional curves (DAC + 12 dB and DAC + 16 dB) above this represent the equivalent sensitivities converted for larger FBHs (12 mm and 15 mm).
- When scanning using these curves and applying *Table 4.2.3 Ultrasonic Acceptance Criteria for steel castings – Using DGS or DAC system* for UT2, any indication below DAC + 12 dB is to be disregarded, and any indication above DAC + 16 dB is to be rejected.

Any indication between these two curves is to be evaluated according to its size, as per *Table 4.2.3 Ultrasonic Acceptance Criteria for steel castings – Using DGS or DAC system*.

■ *Section 3*

Castings for machinery construction

3.5 Non-~~destructive examination~~ Destructive Examination

3.5.1 All piston crowns and cylinder heads are to be examined by ultrasonic testing unless otherwise agreed with LR. Piston crowns intended for engines having a bore size larger than 400 mm and cylinder heads intended for engines having a bore size larger than 300 mm are additionally to be examined by magnetic particle or penetrant testing in accordance with ~~*Ch 4, 1.7 Visual and non-destructive examination*~~ *Ch 4, 1.7 Visual and surface Non-Destructive Examination* and *Ch 4, 1.8 Volumetric Non-Destructive Examination*.

3.5.2 Engine bedplate and transverse girder castings are to be examined by ultrasonic and magnetic particle or penetrant testing in accordance with ~~*Ch 4, 1.7 Visual and non-destructive examination 1.7.9*~~ *Ch 4, 1.7 Visual and surface Non-Destructive Examination (NDE) 1.7.9* and *Ch 4, 1.8 Volumetric Non-Destructive Examination*.

■ *Section 4*
Castings for crankshafts

4.7 Rectification of defective castings

4.7.1 The requirements of *Ch 4, ~~1.9~~ 1.11 Rectification and dressing of castings* apply, except where amended by this Section.

4.7.12 Welds are to be dressed smooth by grinding. The surfaces of the welds and adjacent parent steel are to be proven by magnetic particle and, where appropriate, ultrasonic inspection, *see Ch 4, ~~1.9~~ 1.11 Rectification and dressing of castings ~~1.9.14~~ 1.11.15* and *Ch 4, ~~1.9~~ 1.11 Rectification and dressing of castings ~~1.9.15~~ 1.11.16*.

■ *Section 5*
Castings for propellers

5.5 Quality of castings, inspection, and ~~non-destructive examination~~ Non-Destructive Examination

5.5.5 For all propellers, separately cast blades, and hubs, the surfaces covered by severity Zones A, B and C are to be subjected to ~~liquid~~ penetrant testing, or magnetic particle testing as appropriate to the material type. Testing of Zone A is to be undertaken in the presence of the Surveyor, whilst testing of Zones B and C may be witnessed by the Surveyor upon their request.

5.5.6 If repairs have been made either by grinding or by welding, the repaired areas are additionally to be subjected to ~~liquid~~ penetrant testing (or magnetic particle testing, as appropriate) independent of their location and/or severity zone. Weld repairs are, independent of their location, always to be assessed according to ~~zone A~~ Zone A.

(Part only shown)

5.5.8 The following definitions apply in relation to the assessment of indications when using the ~~liquid~~ penetrant testing method:

5.6 Rectification of defective castings

5.6.1 The rectification of defective castings is to be undertaken in accordance with *Ch 4, ~~1.9~~ 1.11 Rectification and dressing of castings* and the following paragraphs.

5.6.2 Removal of defective material is to be by mechanical means, e.g. by grinding, chipping or milling. The resultant grooves are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defect is to be verified by ~~liquid~~ penetrant testing, or magnetic particle testing as appropriate.

5.6.3 Grinding in severity ~~zone A~~ Zone A may be carried out to an extent that maintains the blade thickness. Repair by welding is generally not permitted in ~~zone A~~ Zone A and will only be allowed after special consideration.

5.6.4 Defects in severity ~~zone B~~ Zone B that are not deeper than $t/40$ mm (t is the minimum local thickness according to the Rules) or 2 mm, whichever is the greater, are to be removed by grinding. Those defects that are deeper may be repaired by welding subject to prior approval of the Surveyor.

5.6.5 Repair welding is generally permitted in severity ~~zone C~~ Zone C.

5.6.11 All welds are to be inspected by the appropriate NDE method, *see ~~Ch 4, 1.7 Visual and non-destructive examination~~ Ch 4, 1.7 Visual and surface Non-Destructive Examination*.

■ *Section 6*
Castings for boilers, pressure vessels and piping systems

6.5 Non-~~destructive examination~~ Destructive Examination

6.5.1 The ~~non-destructive examination~~ Non-Destructive Examination of castings is to be carried out in accordance with the appropriate requirements of *~~Ch 4, 1.7 Visual and non-destructive examination 1.7.7~~ Ch 4, 1.7 Visual and surface Non-Destructive Examination 1.7.7* to *~~Ch 4, 1.7 Visual and non-destructive examination 1.7.11~~ Ch 4, 1.7 Visual and surface Non-Destructive Examination 1.7.11* and *Ch 4, 1.8 Volumetric NDE 1.8.1* to *Ch 4, 1.8 Volumetric 1.8.11*, and additionally as agreed between the manufacturer, purchaser and Surveyor.

■ *Section 7*
Ferritic steel castings for low temperature service

7.5 Non-~~destructive examination~~ Destructive Examination

7.5.1 The ~~non-destructive examination~~ Non-Destructive Examination of castings is to be carried out in accordance with the appropriate requirements of ~~*Ch 4, 1.7 Visual and non-destructive examination 1.7.7*~~ *Ch 4, 1.7 Visual and surface Non-Destructive Examination 1.7.7* to ~~*Ch 4, 1.7 Visual and non-destructive examination 1.7.11*~~ *Ch 4, 1.7 Visual and surface Non-Destructive Examination 1.7.11* and *Ch 4, 1.8 Volumetric Non-Destructive Examination 1.8.1* to *Ch 4, 1.8 Volumetric Non-Destructive E 1.8.11*, and additionally as agreed between the manufacturer, purchaser and Surveyor.

■ *Section 8*
Stainless steel castings

8.6 Non-~~destructive examination~~ Destructive Examination

8.6.1 The ~~non-destructive examination~~ Non-Destructive Examination of castings is to be carried out in accordance with the appropriate requirements of ~~*Ch 4, 1.7 Visual and non-destructive examination 1.7.7*~~ *Ch 4, 1.7 Visual and surface Non-Destructive Examination 1.7.7* to ~~*Ch 4, 1.7 Visual and non-destructive examination 1.7.11*~~ *Ch 4, 1.7 Visual and surface Non-Destructive Examination 1.7.11* and *Ch 4, 1.8 Volumetric Non-Destructive Examination 1.8.1* to *Ch 4, 1.8 Volumetric Non-Destructive Examination 1.8.11*, and additionally as agreed between the manufacturer, purchaser and Surveyor.

■ *Section 9*
Steel castings for container corner fittings

9.2 Chemical composition

9.2.2 The chemical composition of the ladle samples is to comply with recognised National Standards and be within the limits given in *Table 4.9.1 Chemical composition of steel castings for container corner fittings*.

9.4 Mechanical tests

Existing Table 4.9.1 has been deleted and replaced with below:

Table 4.9.1 Chemical compositions of steel castings for container corner fittings

Chemical composition %										
C max.	Mn	Si max.	P max.	S max.	Al acid soluble min. (*see* Notes)	Residual elements (max.)				Total residuals (max.)
						Cu	Cr	Ni	Mo	
0,17–0,23	0,50–1,60	0,60	0,035	0,035	0,015	-	-	0,80	-	1,0

Note 1. The total aluminium content may be determined instead of the acid soluble content. In such cases, the total aluminium content is to be not less than 0,02%.

Note 2. Aluminium may be replaced partly or totally by other grain refining elements as stated in the approved specification.

9.4.2 The results of the tensile tests are to comply with the following:

Yield stress	~~220~~ 275 N/mm^2 min.
Tensile strength	~~430 - 600~~ 480 N/mm^2 min.
Elongation on 5.65 s	25% min.
Reduction of area	40% min.
Charpy V-notch impact test at −20°C:	27 J
Charpy V-notch impact test at −40°C:	21 J

When required by design, Charpy V-notch impact testing at temperatures lower than −40 °C may be required.

Existing paragraphs 9.4.3 and 9.4.4 have been deleted in their entirety.

9.5 Non-~~destructive examination~~ Destructive Examination

9.5.1 A visual check for defects shall be carried out on the exterior and interior surfaces of each fitting. All defective fittings shall be destroyed.

~~9.5.1~~ 9.5.2 Ultrasonic or radiographic testing is to be carried out, in accordance with the appropriate requirements of ~~*Ch 4, 1.7 Visual and non-destructive examination 1.7.10* or *Ch 4, 1.7 Visual and non-destructive examination 1.7.11*~~ *Ch 4, 1.8 Volumetric Non-Destructive Examination 1.8.1* to *Ch 4, 1.8 Volumetric Non-Destructive Examination 1.8.11* respectively, on at least one casting from each cast or from every 400 castings, whichever is the lesser. If defects are found, all fittings in the batch shall be tested. All defective fittings shall be destroyed.

9.6 Repair of defects

9.6.2 ~~Defects which exceed the allowable minus tolerance may be removed by grinding or chipping followed by welding, provided the weld depth does not exceed 40 per cent of the wall thickness and that the following requirements are met:~~ Welding repair is not permitted.

~~(a) welding is not to be carried out in the as-cast condition; the grain structure has to be refined by heat treatment,~~
~~(b) the casting is to be preheated to 80 - 100 °C,~~
~~(c) welding is to be performed only by qualified welders in accordance with a qualified welding procedure,~~
~~(d) all welded castings are to be post-weld heat treated at a temperature not less than 550°C,~~
~~(e) the welded areas are to be ground or machined flush with the adjacent surface and inspected by magnetic particle or dye penetrant examination as appropriate.~~

Chapter 5
Steel Forgings

■ *Section 1*
General requirements

1.2 Manufacture

1.2.15 It is recognised that not every forged component type that may be subject to classification is included in this Chapter. In such cases where the particular component or type is not included, appropriate National/International Standards may be applied, to determine the appropriate testing regime and defect acceptance criteria.

1.8 Visual and ~~non-destructive examination~~ Non-Destructive Examination

1.8.4 When specified in subsequent Sections in this Chapter, or by an approved procedure for welding composite components, *see Ch 5, 1.2 Manufacture 1.2.14*, appropriate ~~non-destructive examination~~Non-Destructive Examination is also to be carried out before acceptance. All tests are to be carried out in accordance with the requirements of *Ch 1, 5 Non-destructive examination*. In addition to the information listed in *Ch 1, 5.6 Non-destructive examination reports*, test results of surface inspections are to include the following items:

(a) Testing method and testing details, including procedure number:
- For liquid penetrant testing, the penetrant system used and viewing conditions (as appropriate to the penetrant technique and media used);
- For magnetic particle testing, method of magnetising, test media, magnetic field strength, magnetic flux indicators (where appropriate) and viewing conditions (as appropriate to the magnetising technique and media used).

(b) Details of weld repair including sketch (where applicable).

1.8.5 Magnetic particle and ~~dye~~ liquid penetrant testing is to be carried out when the forgings are in the finished machined condition, *see also Ch 1, 2.3 Materials Survey Scheme 2.3.5*. For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetisation benches in order to avoid local overheating or burning damage on its surface. Prods are not permitted on finished machined items. The surface inspection is to be carried out before the shrink fitting, where applicable. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyor. Other surface inspection methods, e.g. eddy current testing, may be required by LR as a supplementary method, e.g. for confirming the presence of indications, or for detecting the presence of undocumented weld repairs.

1.8.6 The following definitions apply to indications associated with magnetic particle and ~~dye~~ liquid penetrant inspection:

(a) **Linear indication**. An indication ~~in which the length is at least three times the width~~ with a largest dimension, l, three or more times its smallest dimension, w (i.e. $l \geq 3w$).

(b) **Nonlinear indication**. An indication ~~of circular or elliptical shape with a length less than three times the width~~ with a largest dimension less than three times its smallest dimension (i.e. $l < 3w$).

(c) **Aligned indication**. ~~Three or more indications in a line, separated by 2 mm or less edge-to-edge.~~
- Non-linear indications form an alignment when the distance between indications is less than 2 mm and at least three indications are aligned. An alignment of indications is considered to be a unique indication and its length is equal to the overall length of the alignment.
- Linear indications form an alignment when the distance between two indications is smaller than the length of the longest indication.

(d) **Open indication**. An indication visible after removal of the magnetic particles or that can be detected by the use of ~~contrast dye~~ liquid penetrant testing.

(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of ~~contrast dye~~ liquid penetrant testing.

(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant for the categorisation of indications.

1.8.8 Where required, ultrasonic examination is to be carried out after the forgings have been machined to a condition suitable for this type of examination and after the final heat treatment, but prior to the drilling of oil bores, prior to surface hardening and the machining of bolt threads. Both radial and axial scanning are to be carried out where appropriate for the shape and the dimensions of the forgings being examined. Scanning is to take into account near surface examination. Unless otherwise agreed, examinations are to be carried out by the manufacturer, although Surveyors may request to be present in order to verify that the examination is being carried out in accordance with the agreed procedure.

1.8.13 ~~Advanced NDE methods, as described in *Ch 1, 5.11 Advanced NDE methods*, may be applied to forgings, as appropriate to the material type, thickness, complexity and geometry.~~ Fillet radii should be examined using 45°, 60° or 70° probes, primarily to determine the presence of any cracks within the radiused areas, and as an additional scan to confirm any indications that may have been detected with 0° probe(s) within this area.

1.8.14 For fabricated forgings and weld repairs, weld testing is to be carried out to the appropriate standard, and the acceptance determined by reference to *Table 13.2.7 Acceptance criteria for ultrasonic and phased array testing*.

1.8.15 Construction of DAC curves for straight beam or normal probes are to be performed using reference blocks containing suitably sized Flat Bottom Holes (FBH) spaced over the inspection thickness. Reference blocks are to be manufactured from similar material, with a surface condition similar to that being inspected. Where necessary, allowances are to be made for attenuation losses by performing a transfer correction and adjusting the DAC curve as required. The applied transfer correction (measured in decibels (dB)) is to become the new reference sensitivity, against which indications are evaluated, according to the appropriate table contained in this Chapter, *see Table 5.3.4 Acceptance criteria for ultrasonic testing of shafts and machinery components – DAC Method – Normal probes* and *Table 5.4.6 Ultrasonic Acceptance criteria for crankshafts: DAC Method – Normal probes*.

1.8.16 Distance Gain Size (DGS) diagrams may also be used for normal probes with acceptance criteria and appropriate disc shaped reflector size defined in *Table 5.3.3 Acceptance criteria for ultrasonic testing of shafts and machinery components – DGS Method – Normal probes* and *Table 5.4.5 Ultrasonic acceptance criteria for crankshafts: DGS Method – Normal probes*.

1.8.17 Where angle probes are used, the reference sensitivity is to be established by using either DAC or DGS methods. DAC sensitivity shall be established from 3 mm side drilled holes and the DGS method shall be based on appropriately sized flat bottom holes. Reference blocks are not required for the DGS method unless it is required to check the accuracy of a particular DGS diagram.

1.8.18 Advanced NDE methods, as described in *Ch 1, 5.11 Advanced NDE methods*, may be applied to forgings, as appropriate to the material type, thickness, complexity and geometry. Acceptance and rejection criteria levels are to be as per the applicable Section of this Chapter.

1.8.19 Where such standards are used or referenced as a basis for acceptance and rejection criteria, the quality level is to be equivalent to the allowable criteria stated in the appropriate tables within this Chapter. The quality levels would normally be the highest, or most stringent, to provide reasonable equivalence.

■ *Section 2*
Forgings for ship and other structural applications

2.5 Non-~~destructive examination~~ Destructive Examination

2.5.1 Surface inspections are to be carried out by visual examination and magnetic particle testing (or ~~dye~~ liquid penetrant testing where appropriate)~~.~~, for the purpose of detecting relevant indications and assessing them against the accept/reject criteria stated in *Table 5.2.2 Steel forgings surface inspection*. Personnel engaged in visual examination are to have sufficient knowledge and experience; however, they may be exempted from formal qualification requirements.

2.5.2 Surface inspections are to be carried out in ~~the zones~~ Zones I and II as indicated in *Figure 5.2.1 Inspection zones for magnetic-particle/~~dye~~ liquid penetrant testing on rudder stocks*.

Figure 5.2.1 Inspection zones for magnetic particle /~~dye~~ liquid penetrant testing on rudder stocks

2.5.8 Ultrasonic acceptance criteria are shown in *Table 5.3.3 Acceptance criteria for ultrasonic testing of shafts and machinery components – DGS Method – Normal probes*~~, alternatively see *Ch 1, 5 Non-destructive examination*~~ and *Table 5.3.4 Acceptance criteria for ultrasonic testing of shafts and machinery components – DAC Method – Normal probes*.

■ *Section 3*
Forgings for shafting and machinery

3.5 Non-~~destructive examination~~ Destructive Examination

(Part only shown)

3.5.1 Magnetic particle or liquid penetrant testing (where appropriate) is to be carried out on forgings for main propulsion shafting (including propeller shafts, intermediate shafts, and thrust shafts with minimum diameter not less than ~~100~~ 200 mm), on all connecting rod and tie rod forgings and on the following components:

Cylinder heads (when intended for engines having a bore diameter larger than 300 mm)
Piston crowns (when intended for engines having a bore diameter larger than 400 mm)
Piston rods (when intended for engines having a bore diameter larger than 400 mm)
Turbocharger shaft and rotor (when required by the relevant Rules dealing with engine design and construction)
When intended for engines having a bore diameter larger than 300 mm, bolts and studs for:

- Cylinder heads
- Crossheads
- Connecting rod bearings
- Main bearings
- Crankshafts
- Tie rods
- Holding down bolts
- Propeller blades
- Propeller bosses

Regardless of the above~~-~~, bolts and studs which are subjected to dynamic loading (for example, but not limited to, cylinder head bolts, tie rods, crankpin bolts, main bearing bolts, engine holding down bolts, propeller blade fastening bolts, coupling bolts for crankshafts) and have a diameter of 50 mm or greater are to be subjected to surface examinations

3.5.2 The bores of hollow propeller shafts are to be visually for imperfections uncovered by the machining operation; relevant indications shall be assessed using the accept/reject criteria stated in *Table 5.2.2 Steel forgings surface inspection*.

~~3.5.2~~ 3.5.3 The areas to be tested by magnetic particle or ~~dye~~ liquid penetrant testing are shown in *Figure 5.3.4 Zones for magnetic particle/~~dye~~ liquid penetrant testing on machinery components* and *Figure 5.3.5 Zones for magnetic particle/~~dye~~ liquid penetrant testing on machinery components*. Areas of other components not shown in these figures are to be agreed with the Surveyor. For tie rods, only threaded portions and the adjacent material over a length equal to that of the thread need be tested.

Existing paragraphs 3.5.3 and 3.5.4 have been renumbered 3.5.4 and 3.5.5.

Figure 5.3.4 Zones for magnetic particle/~~dye~~ liquid penetrant testing on machinery components

Figure 5.3.5 Zones for magnetic particle/~~dye~~ liquid penetrant testing on machinery components

Existing paragraph 3.5.5 has been deleted.

3.5.6 Ultrasonic acceptance criteria are shown in *Table 5.3.3 Acceptance criteria for ultrasonic testing of shafts and machinery components – DGS Method – Normal probes* and *Table 5.3.4 Acceptance criteria for ultrasonic testing of shafts and machinery components – DAC Method – Normal probes*. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are acceptable to the Surveyor.

Existing Table 5.3.3 has been deleted in its entirety and replaced with below:

Table 5.3.3 Acceptance criteria for ultrasonic testing of shafts and machinery components – DGS Method – Normal probes

Type of forging	Zone	Allowable disc shape according to DGS (*see* Notes 1 & 2)	Allowable length of indication	Allowable distance between two indications (*see* Note 3)
Propeller shaft Intermediate shaft Thrust shaft Rudder stock	II	outer: $d \leq 2$ mm inner: $d \leq 4$ mm	≤ 10 mm ≤ 15 mm	≥ 20 mm ≥ 20 mm
	III	outer: $d \leq 3$ mm inner: $d \leq 6$ mm	≤ 10 mm ≤ 15 mm	≥ 20 mm ≥ 20 mm
Connecting rod Piston rod Crosshead	II	$d \leq 2$ mm	≤ 10 mm	≥ 20 mm
	III	$d \leq 4$ mm	≤ 10 mm	≥ 20 mm

Note *1*. DGS: Distance Gain Size.

Note *2*. Outer part means the part beyond one-third of the shaft radius from the centre; inner part means the remaining core area.

Note *3*. In case of accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications should be at least the length of the larger indication. This applies to the distance in axial directions as well as to the distance in depth. Isolated indications with shorter distances between them are to be determined as one single indication.

Table 5.3.4 Acceptance criteria for ultrasonic testing of shafts and machinery components – DAC Method – Normal probes

Type of forging	Zone	DAC reference level, based on 3 mm FBH (*see* Notes 1 & 2)	Allowable length of indication	Allowable distance between two indications (*see* Note 3)
Propeller shaft Intermediate shaft	II	Outer: DAC minus 7 dB Inner: DAC + 5 dB	≤ 10 mm ≤ 15 mm	≥ 20 mm
	III	Outer: + 0 DAC Inner: DAC + 12 dB	≤ 10 mm ≤ 15 mm	≥ 20 mm
Thrust shaft Rudder stock	II	Outer: DAC minus 7 dB Inner: DAC + 5 dB	≤ 10 mm ≤ 15 mm	≥ 20 mm
	III	Outer: + 0 DAC Inner: DAC + 12 dB	≤ 10 mm ≤ 15 mm	≥ 20 mm
Connecting rod Piston rod crosshead	II	DAC minus 7 dB	≤ 10 mm	≥ 20 mm
	III	DAC + 5 dB	≤ 10 mm	≥ 20 mm

Note *1*. The requirement of a 3 mm FBH is to standardise the DAC reference blocks for clarity and consistency. The dB value for the FBH/DAC setting is equivalent to the disc-shaped reflector stated above, corresponding to the applicable zone.

Note *2*. Other size FBHs may be used for the DAC Method (and the dB value adjusted accordingly to provide equivalence with the stated FBH/disc-shaped reflector). Where other size FBHs are used, the ultrasonic procedure is to state the equivalence using an appropriate calculation formula.

Note *3*. In case of accumulations of two or more isolated indications which are subject to registration, the minimum distance between two neighbouring indications must be at least the length of the larger indication. This applies to the distance in axial directions as well as to the distance in depth. Isolated indications with shorter distances between them are to be determined as one single indication.

■ *Section 4*
Forgings for crankshafts

4.6 Non-~~destructive examination~~ Destructive Examination

4.6.1 Magnetic particle or ~~dye~~ liquid penetrant testing as detailed in *Ch 5, 1.8 Visual and non-destructive examination 1.8.5* is to be carried out on all forgings for crankshafts. Where applicable, this is to include all surfaces which have been flame-cut, but not subsequently machined during manufacture. Particular attention is to be given to the testing of the pins, journals and associated fillet radii of solid forged crankshafts and to the pins and fillet radii of combined web and pin forgings. The extent of testing is shown in *Figure 5.4.3 Zones for magnetic particle/~~dye~~ liquid penetrant testing on crankshafts*.

Figure 5.4.3 Zones for magnetic particle/~~dye~~ liquid penetrant testing on crankshafts

4.6.2 The manufacturer is to carry out an ultrasonic examination of all crankshaft forgings as detailed in *Ch 5, 1.8 Visual and non-destructive examination 1.8.8*. The extent of ultrasonic testing is shown in *Figure 5.4.4 Zones for ultrasonic testing on crankshafts*.

4.6.4 ~~Ultrasonic acceptance criteria are shown in *Table 5.4.5 Ultrasonic acceptance criteria for crankshafts*. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.~~ Ultrasonic acceptance criteria are shown in *Table 5.4.5 Ultrasonic acceptance criteria for crankshafts: DGS Method – Normal probes* and *Table 5.4.6 Ultrasonic acceptance criteria for crankshafts: DAC Method – Normal probes*. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are acceptable to the Surveyor.

Existing Table 5.4.5 has been deleted and replaced with below:

Table 5.4.5 Ultrasonic acceptance criteria for crankshafts: DGS Method – Normal probes

Type of forging	Zone	Allowable according disc-shape to DGS (*see* Note 1)	Allowable length of indication	Allowable distance between tw indications (*see* Note 2)
Crankshaft	I II III	$d \le 1$ mm (*see* Note 3) $d \le 2$ mm $d \le 4$ mm	Not applicable (*see* Note 4) ≤ 10 mm ≤ 15 mm	Not applicable ≥ 20 mm ≥ 20 mm

Note *1*. DGS: Distance Gain Size

Note *2*. In case of accumulations of two or more isolated indications which are subjected to registration, the minimum distanc between two neighbouring indications is to be at least the length of the larger indication. This applies to the distance in axial directions as well as to the distance in depth. Isolated indications with shorter distances between them are to be determined as one single indication.

Note *3*. For Zone 1 testing, probe selection should take into account the limits of probe beam-path length and depth of beam penetration and should normally be carried out with a minimum probe frequency of 4 MHz.

Note *4*. For Zone 1, indications with an echo height greater than a 1 mm disc-shaped reflector are not acceptable. Indications with an echo height of less than 1 mm are acceptable if they are deemed as point reflectors and have no measurable length.

Table 5.4.6 Ultrasonic acceptance criteria for crankshafts: DAC Method – Normal probes

Type of forging	Zone	DAC reference level, based on 3 mm FBH (*see* Notes 1, 2 & 3)	Allowable length of indication	Allowable distance betwee two indications (*see* Note 5
Crankshaft	I	3 mm DAC minus 19 dB	Not applicable (*see* Note 4)	Not applicable
	II	3 mm DAC minus 7 dB	≤ 10 mm	≥ 20 mm
	III	3 mm DAC + 5 dB	≤ 15 mm	≥ 20 mm

Note *1*. The requirement of a 3 mm FBH is to standardise the DAC reference blocks for clarity and consistency. The dB value for the FBH/DAC setting is equivalent to the disc-shaped reflectors stated in *Table 5.4.5 Ultrasonic acceptance criteria for crankshafts: DGS Method – Normal probes*, corresponding to the applicable zone.

Note *2*. Other size FBHs may be used for the DAC Method (and the dB value adjusted accordingly to provide equivalence with the stated FBH/disc-shaped reflector). Where other size FBHs are used, the ultrasonic procedure is to state the equivalence using an appropriate calculation formula.

Note *3*. For Zone 1 testing, probe selection is to take into account the limits of probe beam-path length and depth of beam penetration, and is normally carried out with a minimum probe frequency of 4 MHz.

Note *4*. For Zone 1, indications with an echo height greater than the DAC reference level are not acceptable. Indications with a echo height of less than the DAC reference level are acceptable if they are deemed as point reflectors and have no measurable length.

Note *5*. In case of accumulations of two or more isolated indications which are subject to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication. This applies to the distance in axial directions as well as to the distance in depth. Isolated indications with shorter distances between them are to be determined as one single indication.

■ *Section 5*
Forgings for gearing

5.7 Non-~~destructive examination~~ Destructive Examination

■ *Section 9*
Stainless steel forgings

9.1 General

9.1.1 Forgings in austenitic and duplex stainless steels are acceptable for use in the construction of cargo tanks, storage tanks and piping systems for chemicals and liquefied gases. They may also be accepted for elevated temperature service in boilers. The allowable number and size of indications in the reference area are given in *Table 5.2.2 Steel forgings surface inspection*. This Table is also applicable to austenitic stainless steel and ferritic-austenitic (duplex) stainless steel forgings, for the purposes of assessing surface indications.

9.1.2 Ultrasonic acceptance criteria detailed in *Table 5.3.3 Acceptance criteria for ultrasonic testing of shafts and machinery components – DGS Method – Normal probes*, *Table 5.3.4 Acceptance criteria for ultrasonic testing of shafts and machinery components – DAC Method – Normal probes*, *Table 5.4.5 Ultrasonic acceptance criteria for crankshafts: DGS Method – Normal probes* and *Table 5.4.6 Ultrasonic acceptance criteria for crankshafts: DAC Method – Normal probes* are intended for *C*, *CMn*, and alloy steel forgings, and do not apply to austenitic stainless steel or ferritic-austenitic (duplex) stainless steel forgings. Examples of standards for acceptance criteria for stainless steel or duplex stainless steel forgings are detailed below, and quality levels are to be agreed with the surveyor. Other National or International Standards may be used, upon agreement with the surveyor.

- ASTM A745/A745M;

- EN 10228-4.

Existing paragraph 9.1.2 has been renumbered 9.1.3.

9.6 Non-~~destructive examination~~ Destructive Examination

Chapter 6
Steel Pipes and Tubes

■ *Section 1*
General requirements

1.7 Testing material

1.7.2 Where heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size, manufactured from the same ~~types~~ heat of steel and subjected to the same finishing treatment in a continuous furnace, or heat treated together in the same batch type furnace.

1.7.3 Where no heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size manufactured by the same method from material of the same ~~type~~ heat of steel.

Published by Lloyd’s Register Group Limited
Registered office (Reg. no. 08126909)
71 Fenchurch Street, London, EC3M 4BS
United Kingdom